GranuFlow Process Development

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ABSTRACT

A continuous pilot-scale test of the GranuFlow Process was conducted using a screen-bowl centrifuge for the dewatering and reconstitution of column flotation concentrate at a coal preparation plant in Virginia. In this test, a slipstream of the fine-clean-coal slurry from the column flotation concentrate was treated with a bitumen emulsion before dewatering. The treated products from the screen-bowl centrifuge appeared to be dry and in a free-flowing granular form, while the untreated products were wet, sticky, and difficult to handle. Specifically, test results indicated that the average moisture contents of the dewatered coal were 35.7, 35.5, 32.6, 29.9, and 26.5 wt% with Orimulsion additions of 0, 0.7, 3.2, 4.8, and 6.4 wt%, respectively. The handleability and dust reduction of the dewatered coal product were also vastly improved. A preliminary cost estimate of using Orimulsion in the GranuFlow Process is also included. Because of the simplicity of the process and the low cost of the bitumen emulsion, the commercialization potential of the GranuFlow Process is significant.

INTRODUCTION

Under the Department of Energy's (DOE) advanced fine-coal dewatering contract (DE-AC22-94PC94155), managed by the University of Kentucky Center for Applied Energy Research (UKCAER), the Coal Preparation Division of the Federal Energy Technology Center (FETC) performed a series of pilot-scale centrifuge dewatering tests at the Powell Mountain Coal Company Mayflower Plant located in St. Charles, Virginia. The test series featured the FETC-developed and -patented GranuFlow Process, a concept that combines fine-coal dewatering and reconstitution into one step[1]. This process aimed at improving fine-coal handleability and reducing product moisture content[2]. It minimizes coal losses and dust emissions during transportation, handling, and storage, and produces an economically reconstituted fine-clean-coal product that is easy to handle [3, 4]. The process requires the addition of a small amount of a specially selected binding material to the fine-clean-coal slurry before filtration or centrifugation. The process is simple. It enhances the existing dewatering centrifuge to produce fine-coal product with multiple benefits in a one-step process at a lower cost. This report summarizes the results of applying the GranuFlow Process to column flotation clean-coal concentrate in a pilot plant scale screen-bowl centrifuge, using Orimulsion as the binder.

EXPERIMENTAL

An Upper Mason seam high-sulfur (2.01 wt% sulfur) coal was processed at the Mayflower Coal Preparation Plant. The column flotation slurry concentrate had about 15 wt% solids and contained 6.5wt% ash. The particle size was 90 percent passing 150 mesh (106 μm) with mean size (d_{50}) of 25 μm. The bitumen emulsion used in the study was Orimulsion, a high-Btu bitumen-in-water emulsion from Venezuela. It is being used as a fuel for power generation in several countries. The emulsion contains about 70wt% bitumen, 30wt% water, and a trace amount of surfactants. The cost of Orimulsion is about the cost of coal on an equal Btu basis.

Centrifuge Dewatering Test Equipment

The CAER centrifuge dewatering test circuit at the Mayflower Plant was setups outside the plant and included a 500-gallon (1893-liter) slurry feed tank, a 5-gallon (18.9-liter) Orimulsion holding container, a gear pump, and 18-inch (45.7-cm) Decanter screen-bowl centrifuge, and a product conveyer. The feed tank was set on a platform 30-ft (9.14-m) above ground. The centrifuge was set on the ground about 30-ft (9.14-m) away from the feed tank. Slurry was gravity fed to the centrifuge via a 2-inch (5.08-cm) pipe connected from the tank to the centrifuge. A tube valve, located about 3-ft (0.914-m) from the centrifuge feed inlet, was used to control the feed rate. Orimulsion was pumped directly into the slurry feed line about 1-ft (0.305-m) away from the bottom of the feed tank providing about 28-ft (8.54-m) on-line mixing distance. The capacity of the centrifuge was around 1-2 tph of coal, and the rotation speed was at 1,000 rpm which provided a force field of 226 G. The screen opening was about 28 mesh (500μm).

Test Procedure

A slurry feed rate to the centrifuge was kept constant at about 20 gpm (75.7 liter/m) which provided about 3/4 tons of coal per hour of operation. The dewatering tests started without adding Orimulsion to obtain the baseline data for the screen-bowl centrifuge dewatering. At the end of 30 minutes of baseline operation, the Orimulsion pump was turned on. Generally, samples of the slurry feed, dewatered product coal, and main and screen effluents were collected at 10 and 20 minutes of operation for each test condition. Timed samples at a predetermined time were usually taken after 20 minutes of operation for material balance determination. At the end of every test condition, the Orimulsion pump setting was changed to a new setting. Samples were analyzed for product moisture, solids and ash contents, and product dust index.

RESULTS AND DISCUSSION

Effect of Orimulsion Concentration on Product Moisture and Handleability

Test results shown in Figure 1 indicates that the average moisture contents of the dewatered coal were 35.7, 35.5, 32.6, 29.9, and 26.5 wt% with Orimulsion additions of 0, 0.7, 3.2, 4.8, and 6.4 wt%, respectively. In this series of tests, the product moisture reductions were superior to those obtained at FETC’s 6-inch lab screen-bowl centrifuge when testing similar sizes of other coals, and were almost equivalent to results from FETC’s 14-inch (35.6-cm) high-g solid-bowl centrifuge. This could be due to the higher hydrophobicity of coal itself and the surface hydrophobicity generated by the flotation collector in the column flotation. Also, the size of the centrifuge, as a 18-inch (45.7-cm) centrifuge is more representative of a true industrial scale unit than a 6-inch (15.2-cm) lab-scale unit, and differences in centrifuge design contributed to this.

The handleability of the centrifuge product was greatly improved with the addition of Orimulsion. Free flowing granules, as opposed to wet lumpy material, were clearly observed at an Orimulsion addition of 3.2 wt% and above.

The improved handleability of the product was also indicated by the formation of product piles discharged from the conveyer. During the tests, two product coal piles were formed under the conveyer. The primary discharge pile was formed at the very end of the conveyer belt due to free-falling coal-granules. The second discharge pile was formed under a conveyer scraper which was located about 12-inches underneath the end of conveyer belt. The Orimulsion treated primary discharge pile showed a much smaller angle of repose than the untreated primary discharge coal pile. The angle of repose is the angle between the horizontal and the slope of a heap of material dropped from some elevation. The smaller the angle of repose the more flowable is the material. Also, most of the Orimulsion treated coal ended in the primary discharge pile, while most of the untreated coal ended in the secondary discharged pile.

Effect of Orimulsion Concentration on Product Dust Index

To evaluate the performance of the GranuFlow Process for dust control, FETC adopted a simple Ro-Tap dry screening process to experimentally measure the dust index (Ii) of the cakes with a constant amount of stress applied. A dust reduction efficiency (E) is calculated based on the following equation.

$$E = \frac{I_o - I_i}{Io} \times 100$$

where, E = dust reduction efficiency of dry cake, %.

l_o = dust index of coal, cumulative weight percent of feed coal finer than 150 mesh (106μm) by wet screening.

I_i = dust index of cake, cumulative weight percent of dry cake finer than 150 mesh (106μm) after Ro-Tapping for 5 minutes.

The dust index of the feed coal, l_o, was 91wt% passing 150 mesh (106μm) obtained from a wet screen analysis. The average dust indices of the Orimulsion treated dry product, I_i, were 82, 56, 12, 5, and 2 wt% using Orimulsion dosages of 0, 0.7, 3.2, 4.8, and 6.4 wt%, respectively. Dust reduction efficiency as shown in Table 1 indicated that more than 85 wt% of the dust (material finer than 150 mesh) was reduced by agglomeration at 3.2 wt% Orimulsion. The dust reduction efficiency reached 95 and 98 wt% at 4.8 and 6.4 wt% Orimulsion additions, respectively.

Effect of Orimulsion Treatment on Product Recovery, Product Ash, and Effluent Solids Reductions

The Orimulsion treatments dramatically reduced the solids content in both the screen and main effluents. As a result, the dewatered coal recovery, as shown in Table 2, increased about 45 wt% from 64.7 wt% to 94.1 wt% at Orimulsion dosages of 0 and 6.4 wt%, respectively. The solids reduction in the main effluent alone accounted for about a 17.5 wt% increase in the dewatered product at the Orimulsion dosage of 6.4 wt%. The benefit of these solids reduction is threefold, (1) increased product recovery by 45 wt%, (2) reduced polymer dosage in the waste slurry thickener by 70 wt%, and (3) extended lifetime of the slurry impoundment by more than 70 wt%.

Table 1 shows the product ash contents, and effluent ash and solids content. It is interesting to note that the average screen-bowl product ash content was 4.4 wt%, which was much lower than the flotation product ash content of 6.5 wt%. Evidently, centrifuge dewatering provided some additional ash reduction. The results also indicated that the bitumen in the Orimulsion selectively agglomerated coal particles but not ash-forming particles, resulting in an increase in the effluent solids ash content and product recovery.

Potential Benefits in Commercial Applications The process has a variety of potential benefits, some of which may be more important than others depending on the particular application. Some commercial benefits are as follows: (1) increased amounts of fine coal can be added to utility plant feedstocks without creating handling problems, (2) the top size of coal fed to a preparation plant can be reduced to take advantage of increased liberation in order to improve the quality of the clean-coal product, (3) coal fines (valuable fuel) can be reclaimed from waste ponds with attendant cleanup of waste sites, and (4) handleability during transportation can be improved by alleviating dust and freezing problems.

Cost Estimation The cost of Orimulsion at a sea port in the southeastern U.S. is around $50 per ton. When using a bitumen dosage around 6 wt% (which is equivalent to an Orimulsion dosage of 8.6 wt%), this would add $4.30 to each ton of fine coal product. But about half of the cost of Orimulsion can be credited as additional salable Btus at the price of coal (~$25/ton). Thus, the true cost may be $2 per ton of fine coal. If this treated fine coal is about 10-20 wt% of the coal shipment sold to a utility, the actual added cost per ton of shipped coal is around $0.2-$0.4. This cost estimation does not include any cost savings or benefits from using Orimulsion. The major cost savings could come from (1) more recoverable and handable low-cost fine coal, (2) less wind loss during transportation, (3) longer life times for waste impoundments, (4) elimination of thermal drying, and (5) less need for dust suppressants or freeze conditioning agents. Also, the coal preparation cost will be reduced because of the increased fine-coal recovery.

CONCLUSIONS

1. The GranuFlow Process was effective in the dewatering of ultra-fine-clean coal using a screen-bowl centrifuge. The process in general improved clean-coal handleability, solids recovery, moisture contents and dustiness of the final product. The addition of Orimulsion reduced the amount of solids lost in the main and screen bowl effluents by about 30 wt%.
2. Addition of about 6.4 wt% of Orimulsion to the clean-coal slurry lowered the moisture content of the final product from 35.7 to 26.5 wt% and improved coal recovery from 64.7 to 94.1 wt%.
3. Addition of 4.8 wt% Orimulsion reduced the main centrifuge effluent solids from 3.4 to 1.1 wt%. Similarly, the screen effluent solids were reduced from 44.7 to 1.5 wt%.
4. In general the dewatering results obtained with the 18-inch diameter pilot scale centrifuge was much better than those obtained with a smaller 6-inch diameter laboratory unit.

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DISCLAIMER

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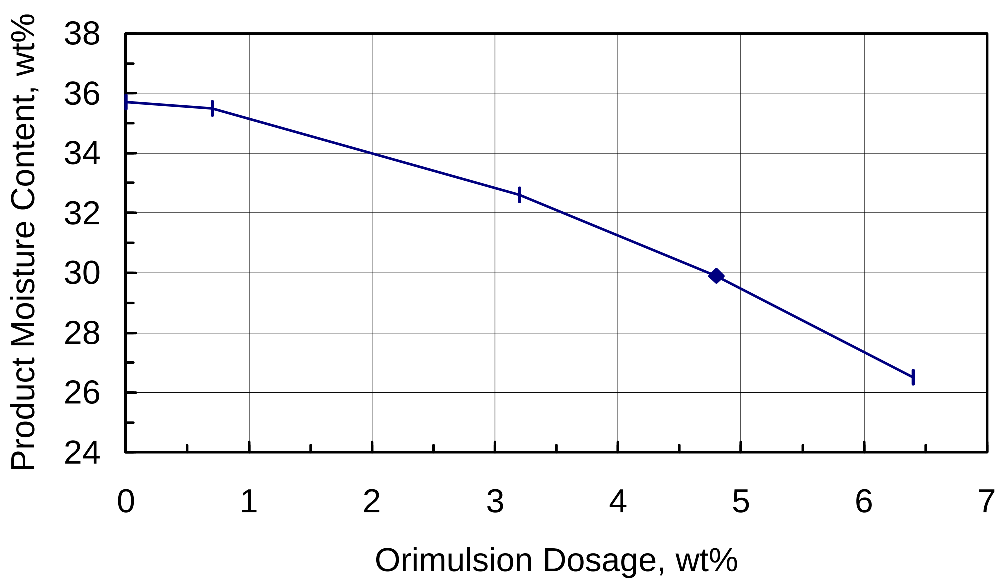

Figure 1. Centrifuge product moisture contents of the column flotation concentrate at Mayflower Coal Preparation Plant (91 wt% passing 150 mesh coal slurry at 15 wt% solids and 6.5 wt% ash).

Table 1. GranuFlow Process testing results on column flotation concentrate from Mayflower plant. (at 20 gpm feed rate, 15 wt% slurry solids, 91 wt% minus 150 mesh, and 6.5 wt% ash in slurry solids)

Test No	Orimulsion, wt%	Product Moisture, wt%	Product Ash, wt%	Main Effluent Solids wt%	Main Effluent Ash, wt%	Screen Effluent Solids, wt%	Screen Effluent Ash, wt%	Dust Index	Dust Reduction Efficiency%
MF 1-1	0	35.7	4.4	3.4	14.0	44.7	9.3	82	10
MF 1-2	0.7	35.5	4.4	3.0	16.1	33.7	9.3	56	38
MF 1-3	3.2	32.8	4.4	2.8	17.5	9.6	11.3	14	85
MF 1-4	4.8	28.3	4.3	1.1	31.8	1.5	16.9	3	97
MF 1-5	6.4	26.5	4.4	NA*	NA*	3.1	11.8	2	98
MF 1-6	4.8	31.4	4.4	2.5	16.8	3.3	13.2	7	92
MF 1-7	3.2	32.4	4.5	3.3	16.9	8.5	11.1	9	90

* No sample (WP: gf-mayf1.res)

Table 2. Approximate solids balance for centrifuge products from the column flotation concentrate from the Mayflower plant. (18-inch centrifuge at 1000 rpm and 226 G-force)

Test No.	Orimulsion, wt%	Solids Balance, wt%			
		Feed	Product	Main Effluent	Screen Effluent
MF 1-1	0	100	64.7	22.5	12.8
MF 1-2	0.7	100	73.1	18.0	8.9
MF 1-3	3.2	100	82.2	15.3	2.5
MF 1-4	4.8	100	93.5	6.1	0.4
MF 1-5	6.4	100	94.1	5.0*	0.9
MF 1-6	4.8	100	86.7	12.4	0.9
MF 1-7	3.2	100	83.5	14.1	2.4

(WP: gf-mayf1.mb)

* This data was calculated by using 1.1 wt% of the main effluent solids from MF1-4.